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(54) **FORMATION OF BORIDE BARRIER LAYERS USING CHEMISORPTION TECHNIQUES**

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(51) **Int. Cl.**^{7} **H01L 21/4763**
(52) **U.S. Cl.** **438/627**; 438/628
(58) **Field of Search** 438/584, 627, 438/628

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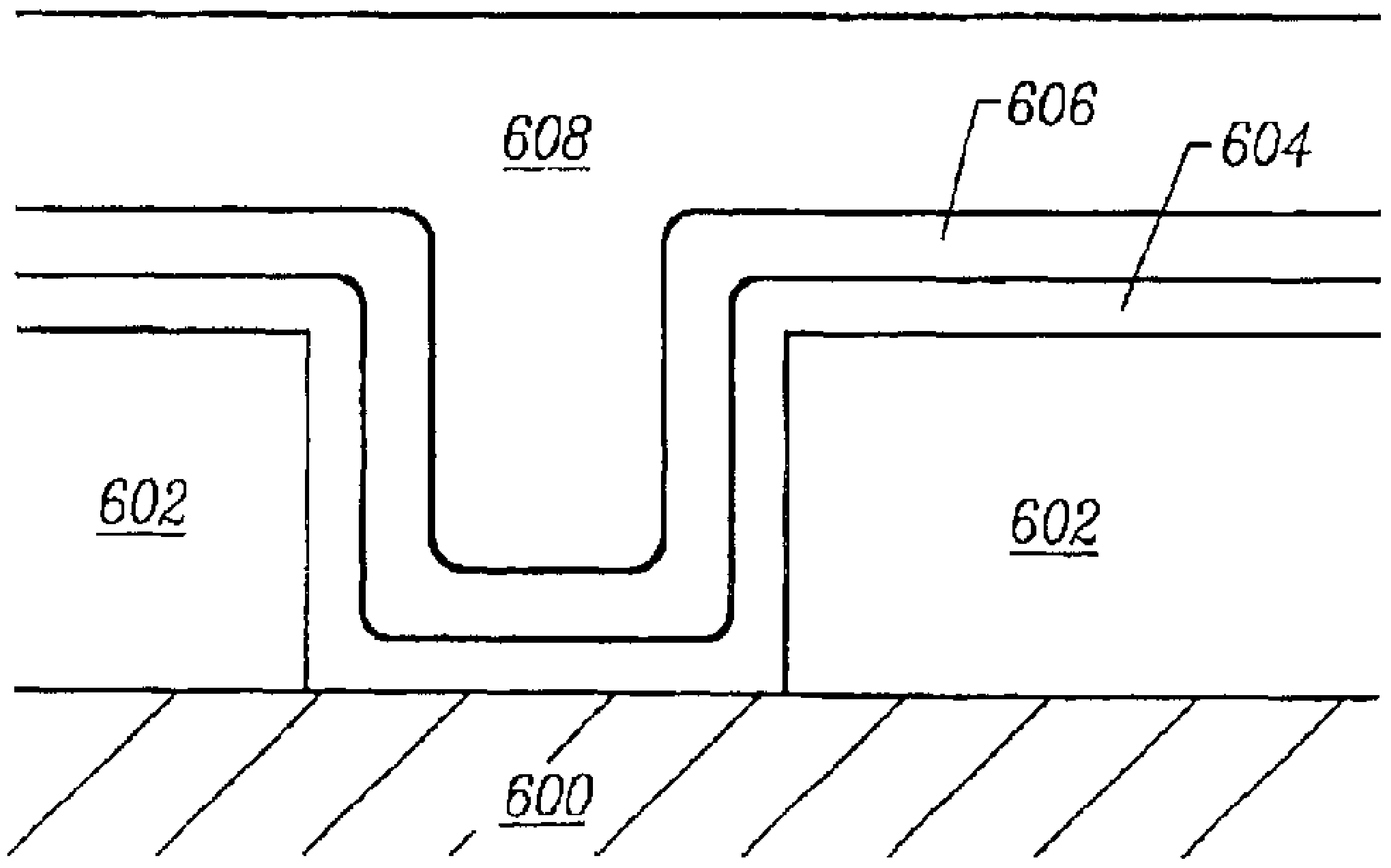
(57) **ABSTRACT**

A method of forming a boride layer for integrated circuit fabrication is disclosed. In one embodiment, the boride layer is formed by chemisorbing monolayers of a boron-containing compound and one refractory metal compound onto a substrate. In an alternate embodiment, the boride layer has a composite structure. The composite boride layer structure comprises two or more refractory metals. The composite boride layer is formed by sequentially chemisorbing monolayers of a boron compound and two or more refractory metal compounds on a substrate.

34 Claims, 7 Drawing Sheets



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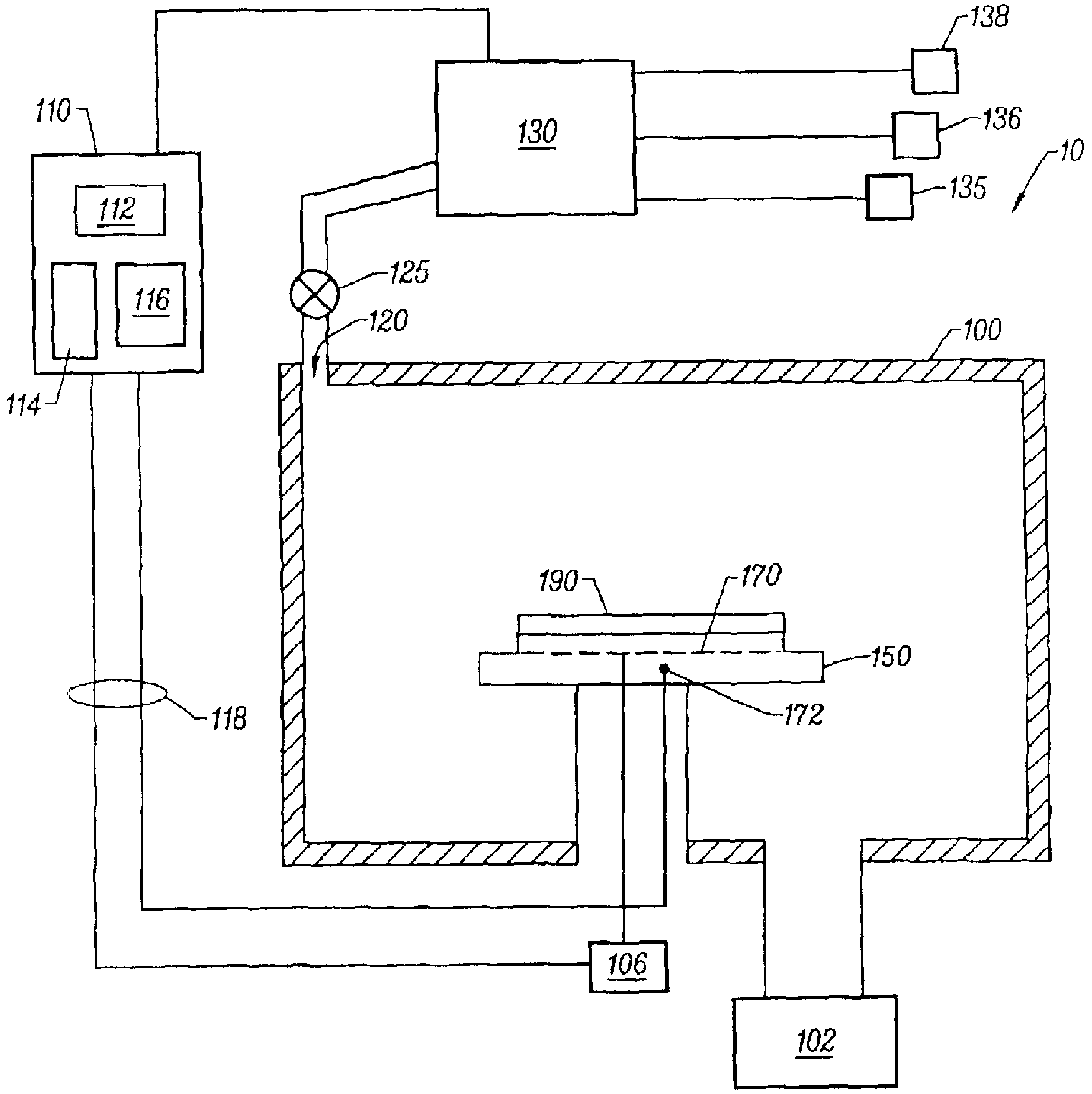
138
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110
112
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114
125
120
100
190
170
150
172
118
106
102

FIG. 1

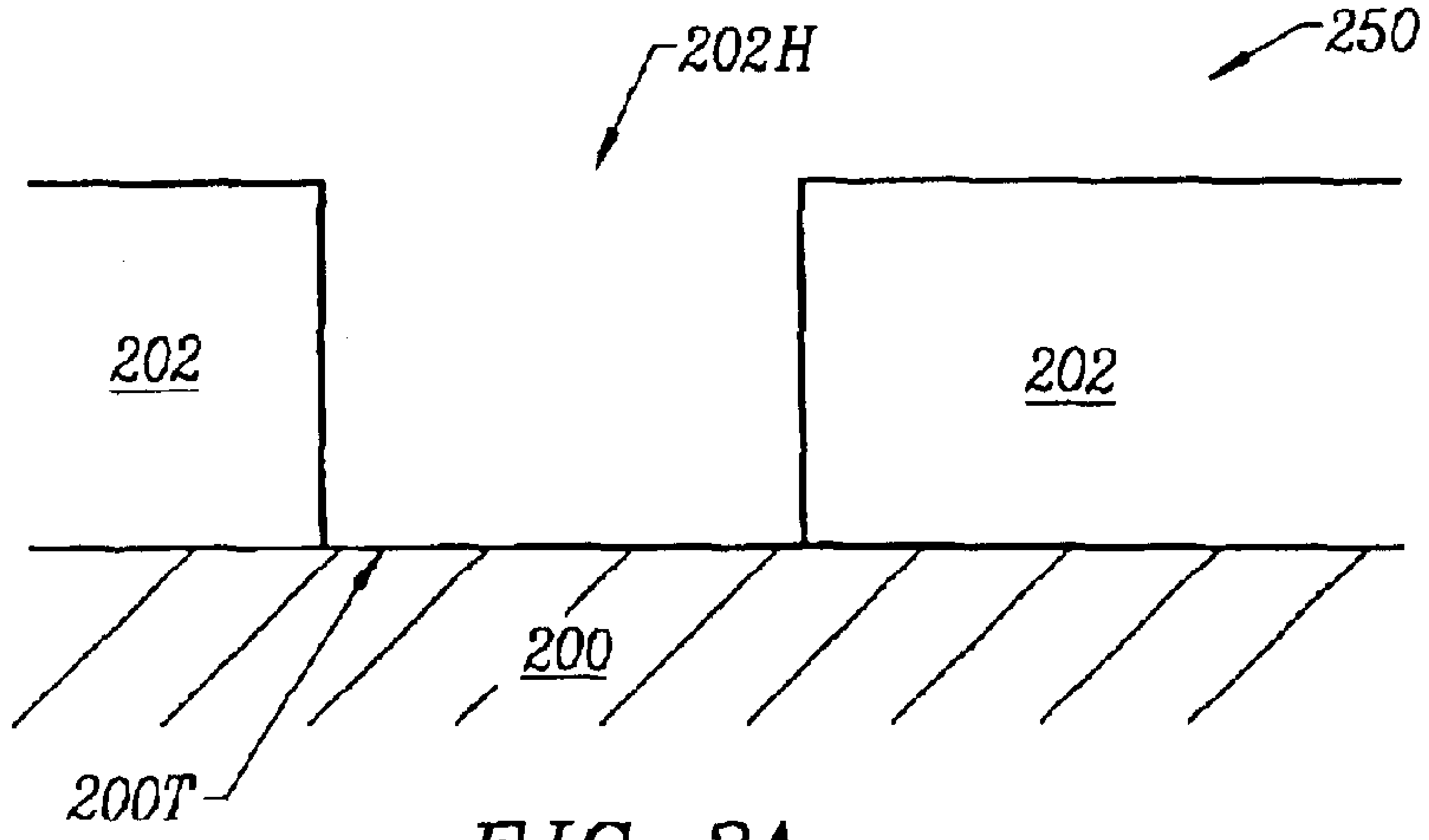

FIG. 2A

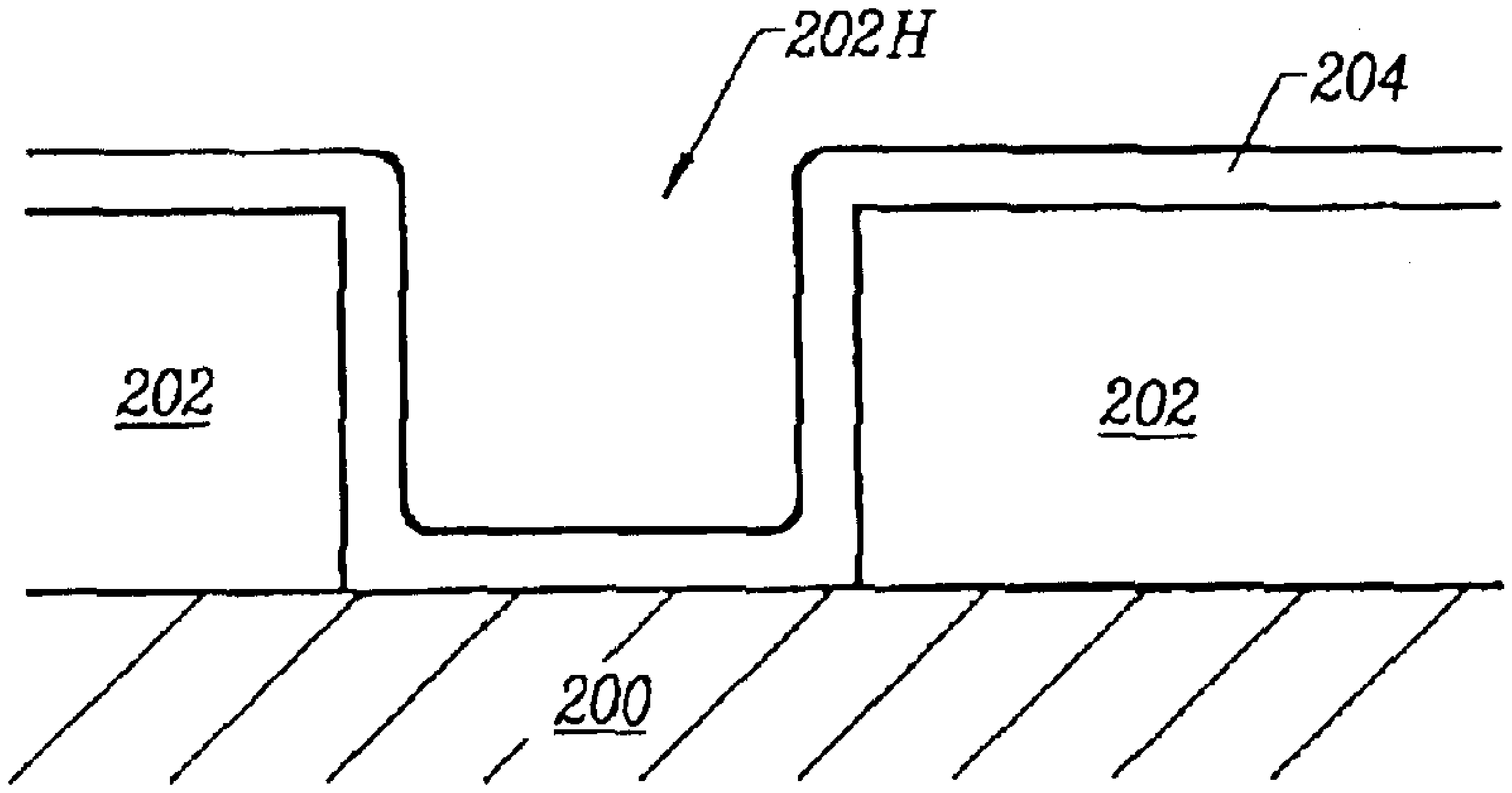

FIG. 2B

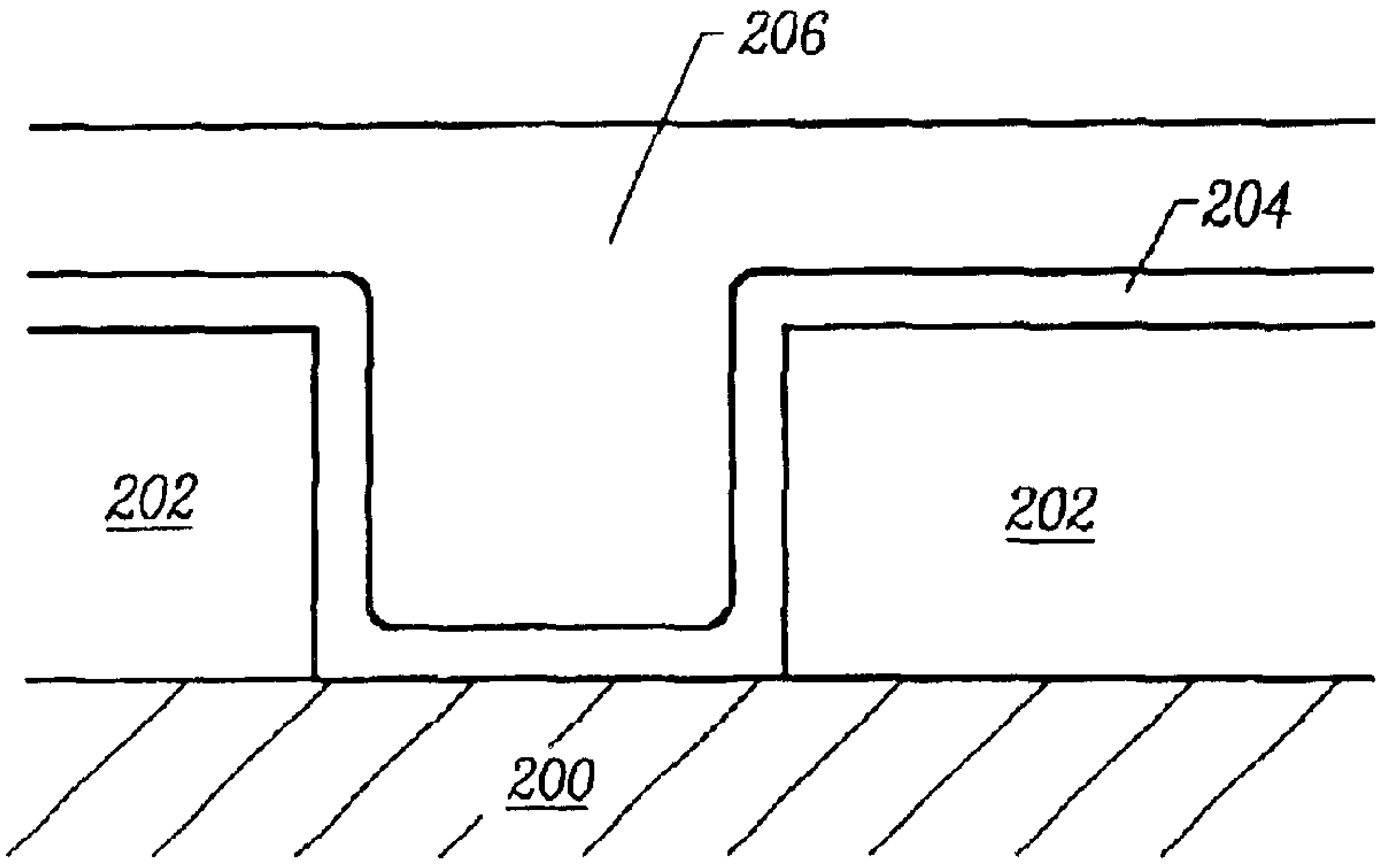

FIG. 2C

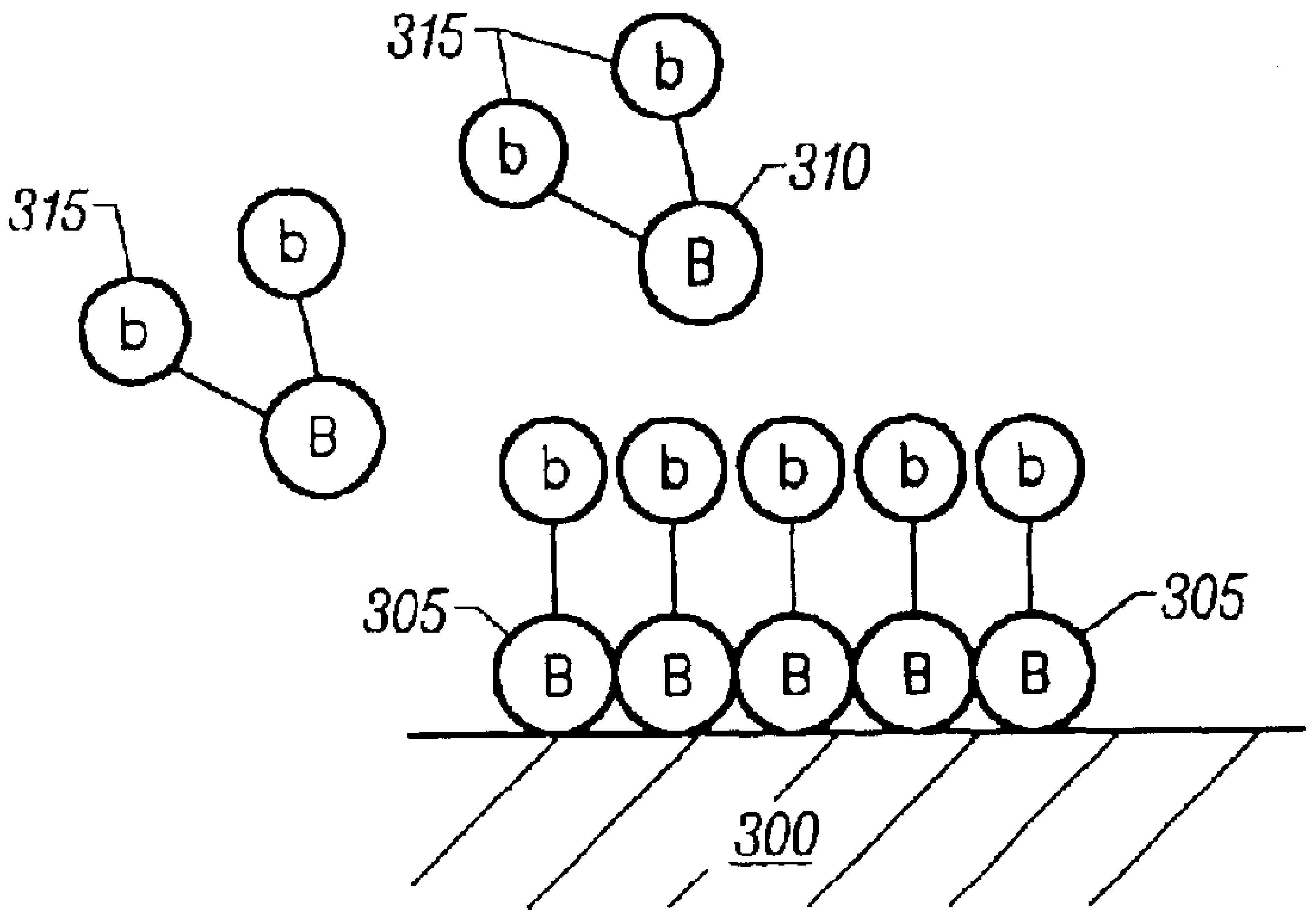

FIG. 3A

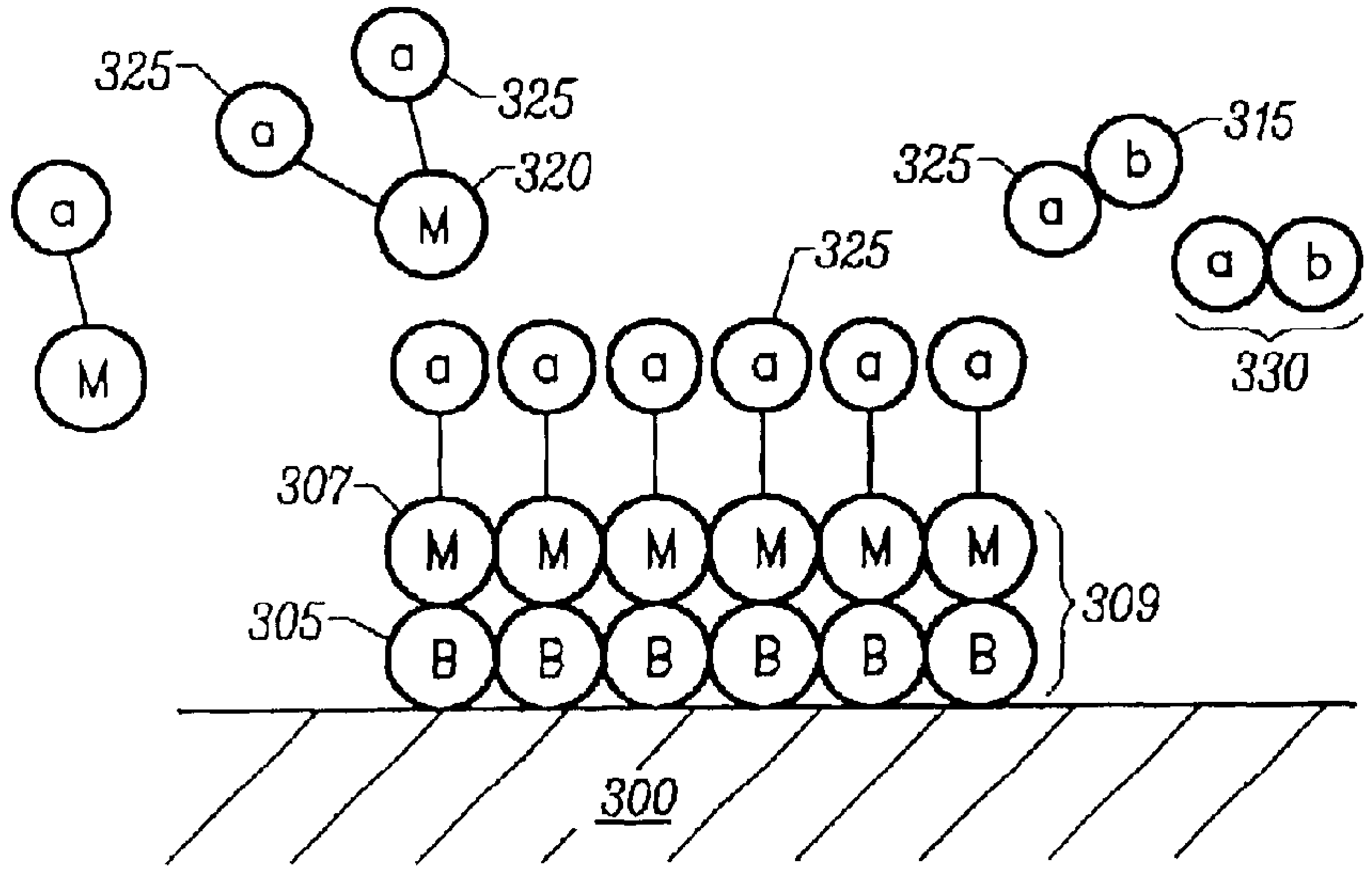

FIG. 3B

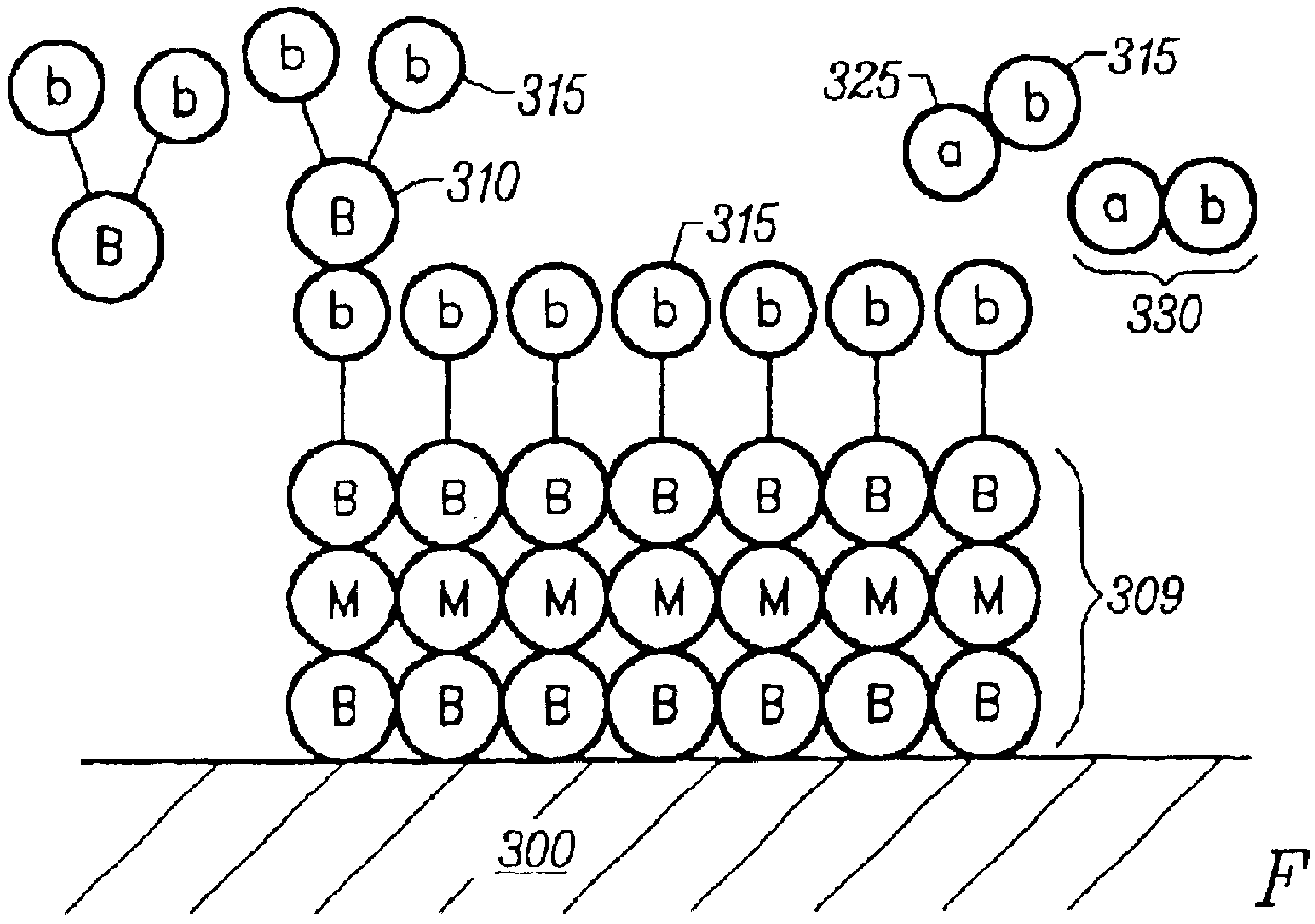

FIG. 3C

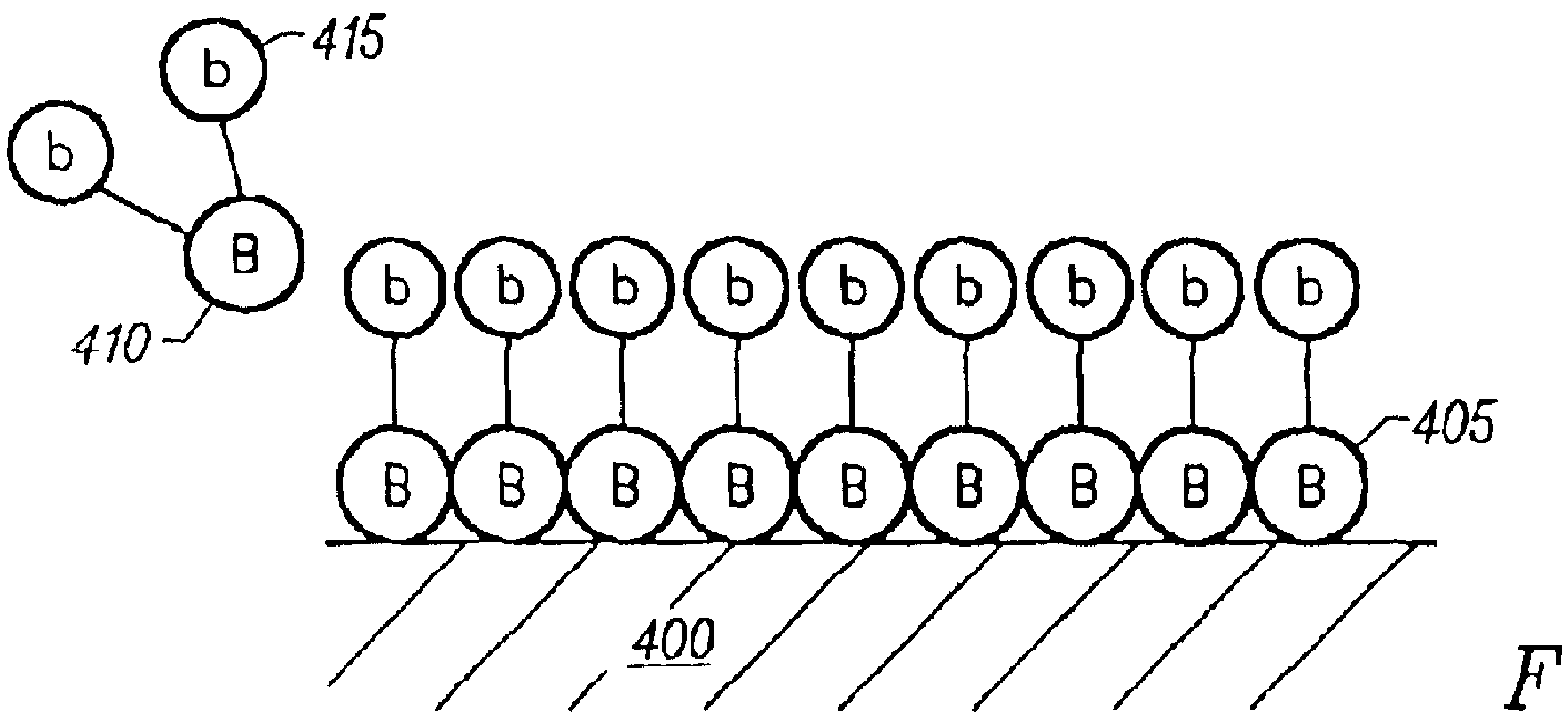

FIG. 4A

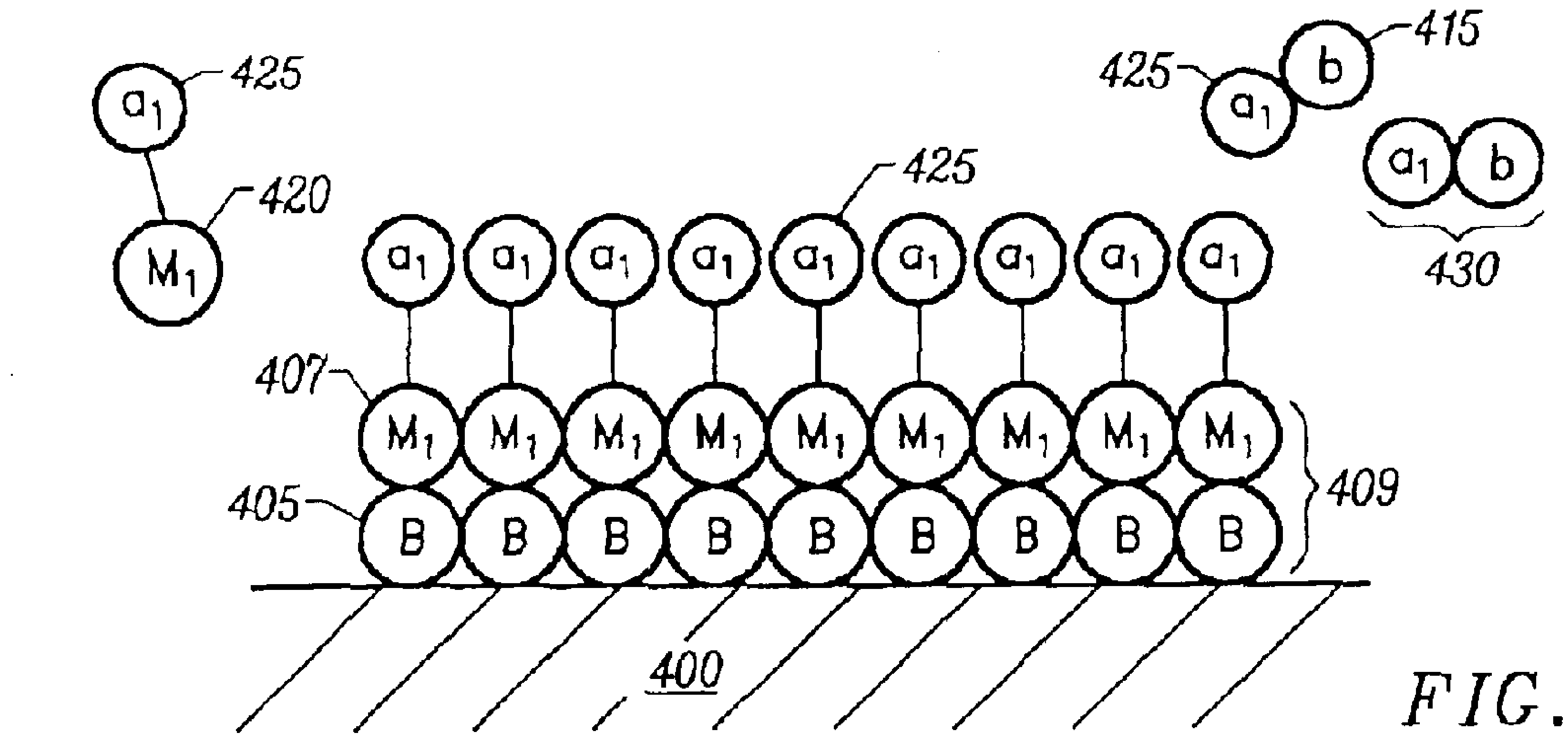

FIG. 4B

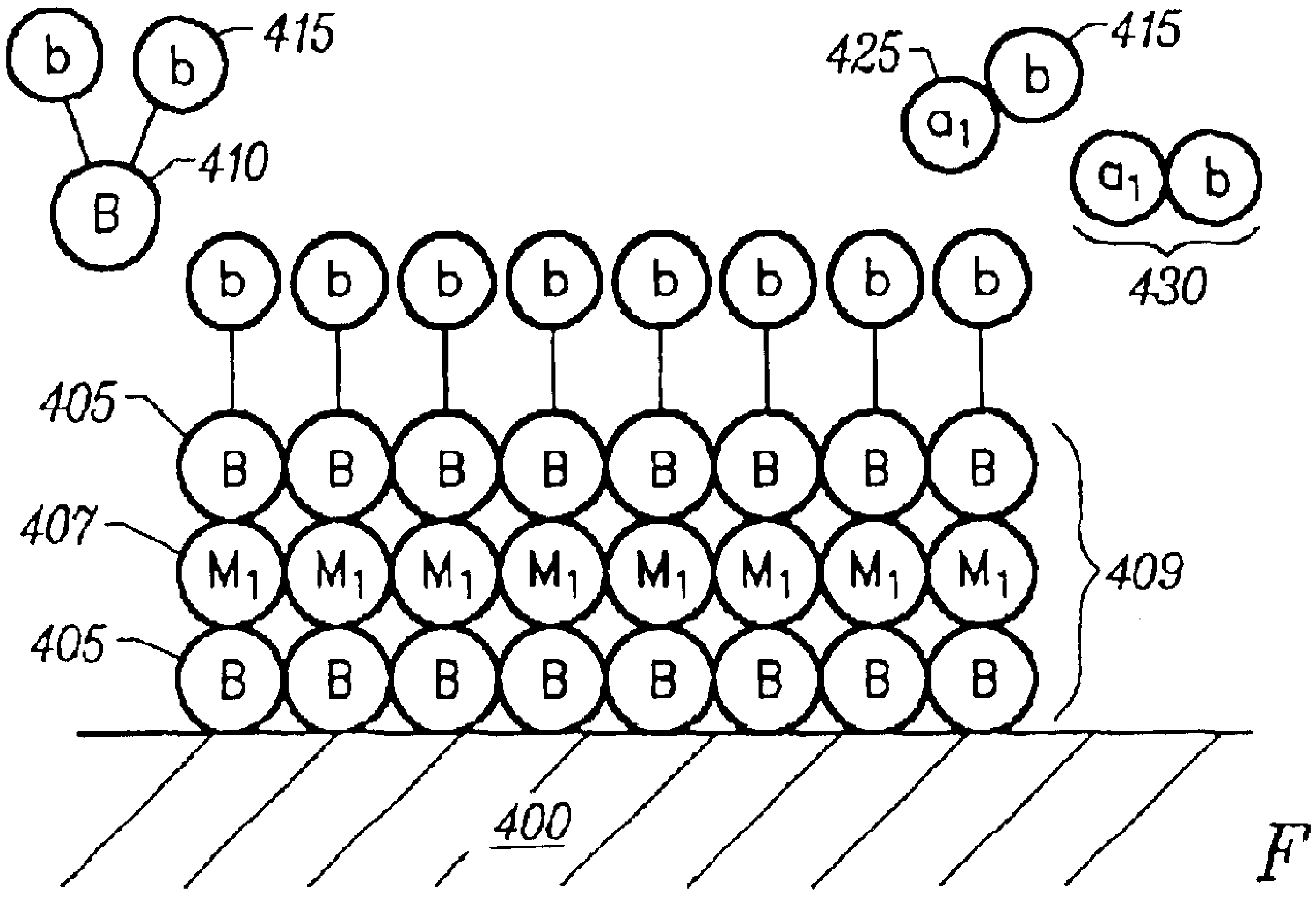

FIG. 4C

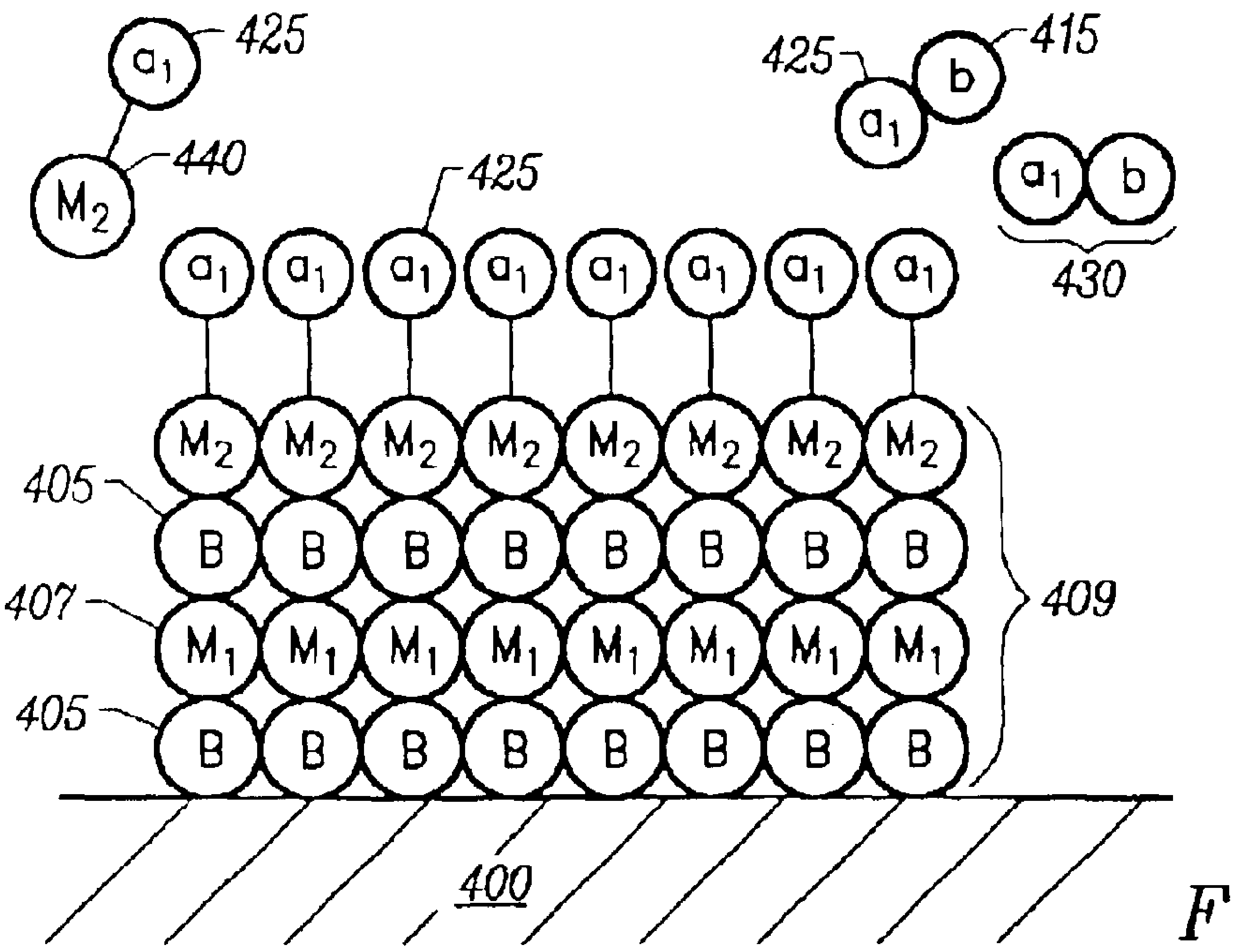

FIG. 4D

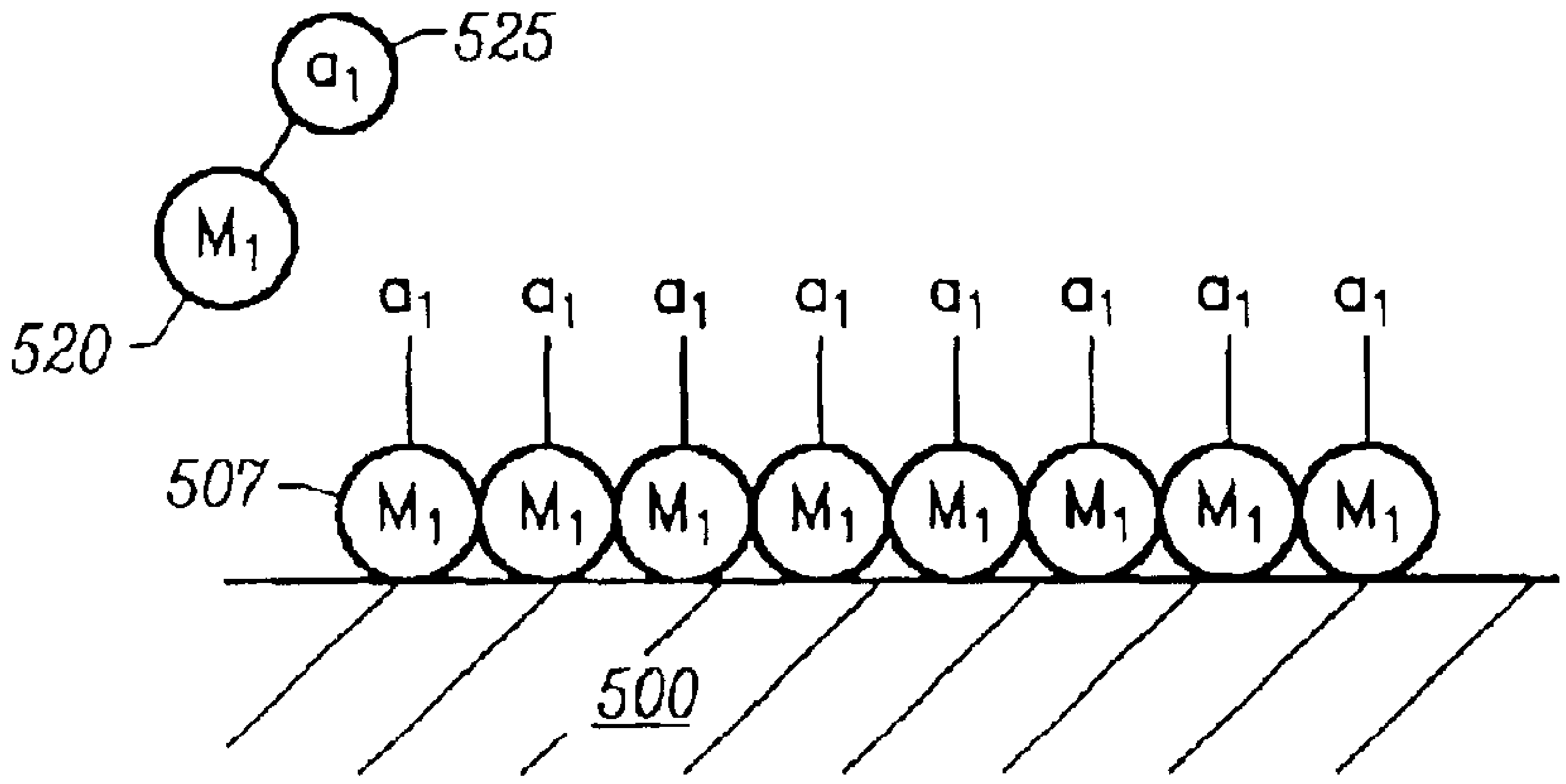

FIG. 5A

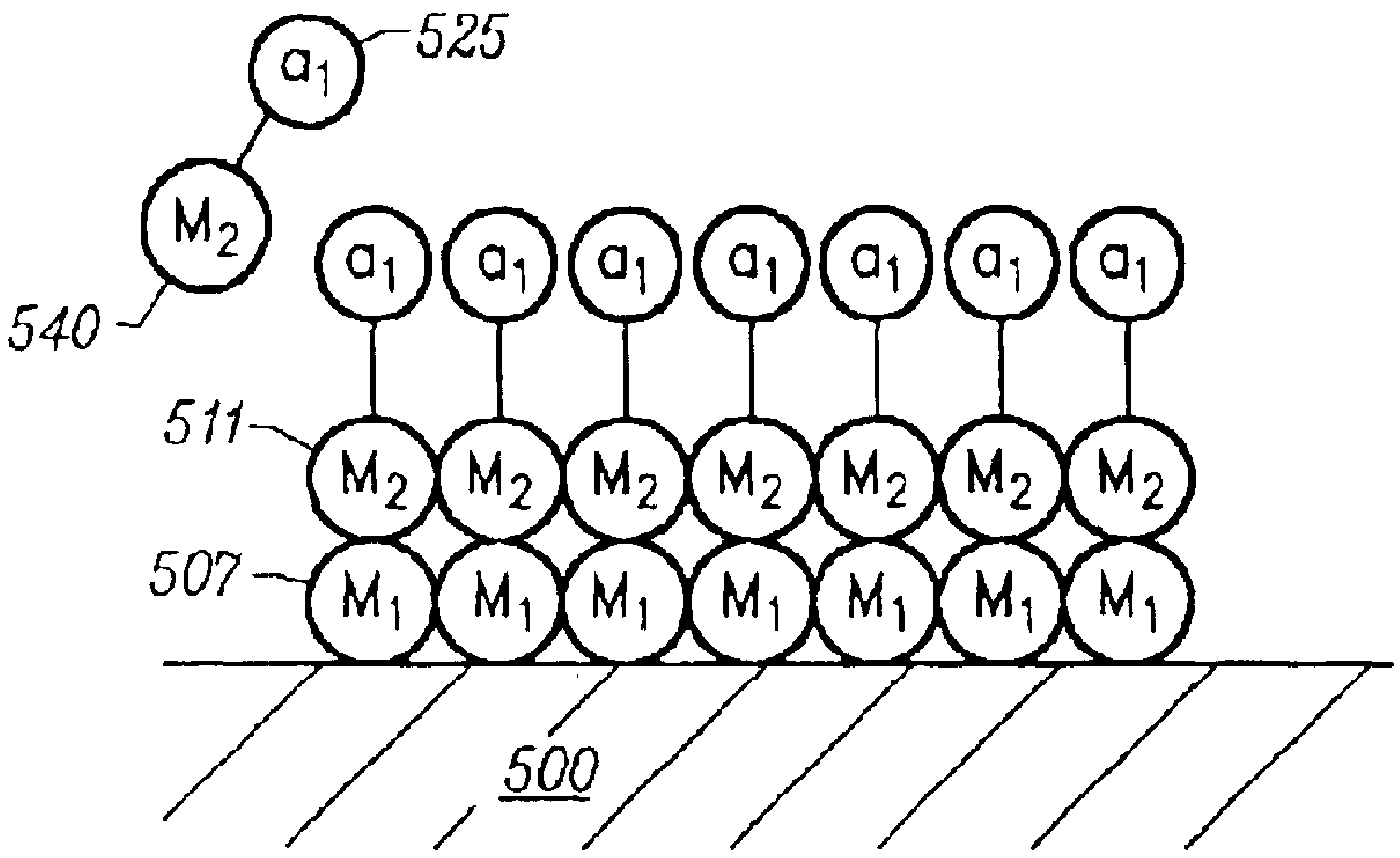

FIG. 5B

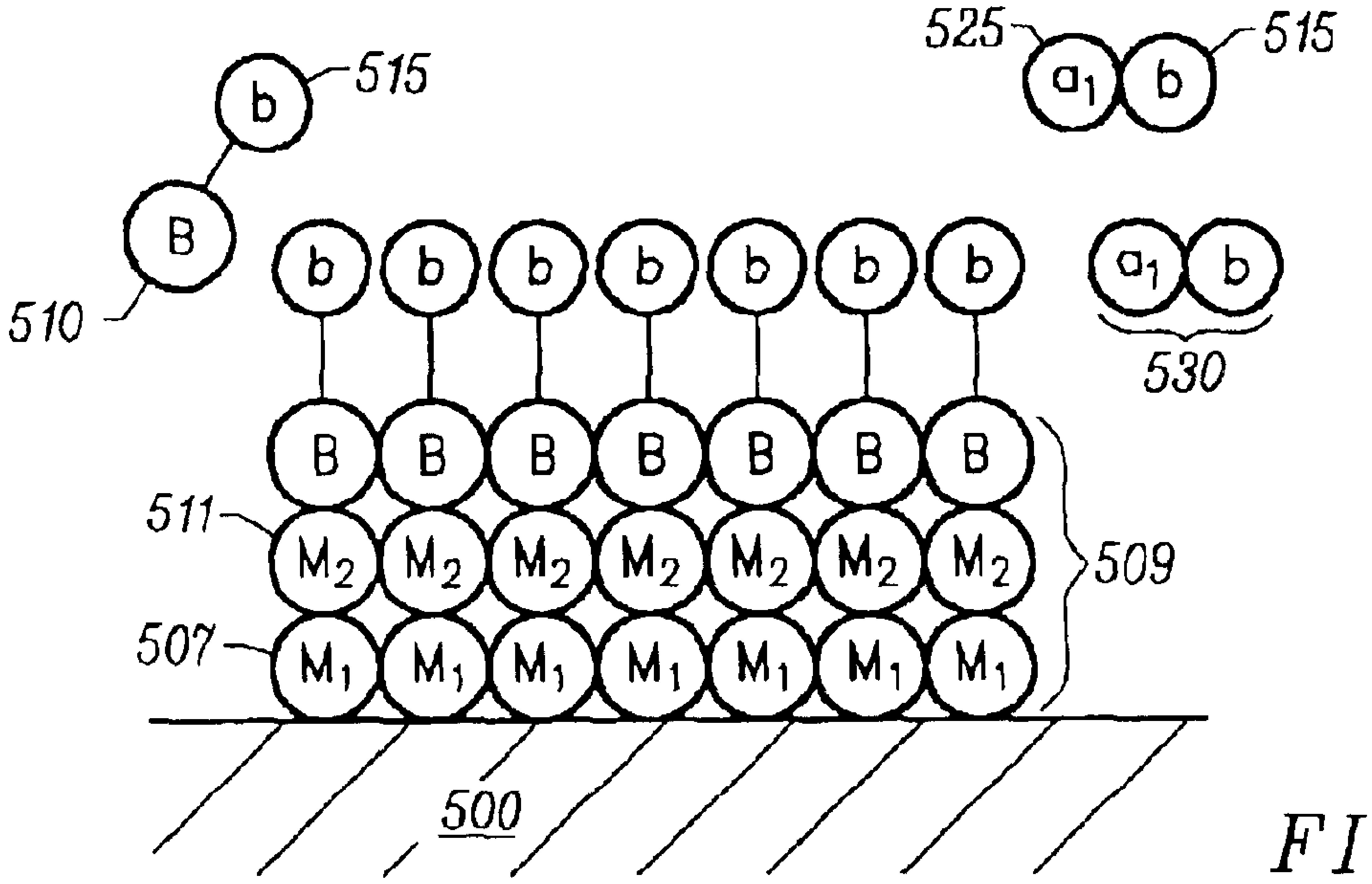
525
515
a_1
b
510
B
b
B
M_2
M_1
511
507
509
530
500

FIG. 5C

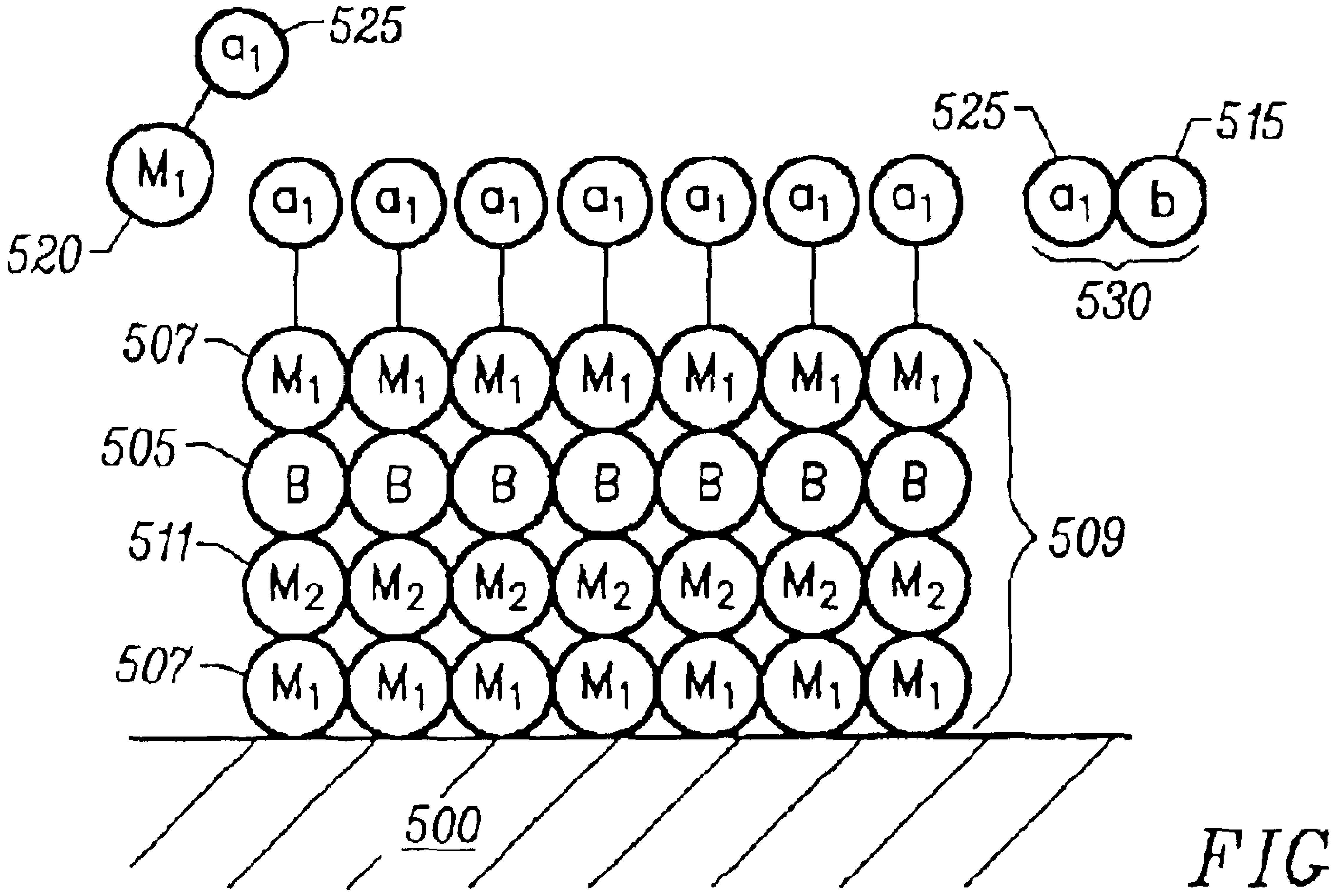
525
520
M_1
a_1
515
b
507
505
511
509
530
B
M_2
500

FIG. 5D

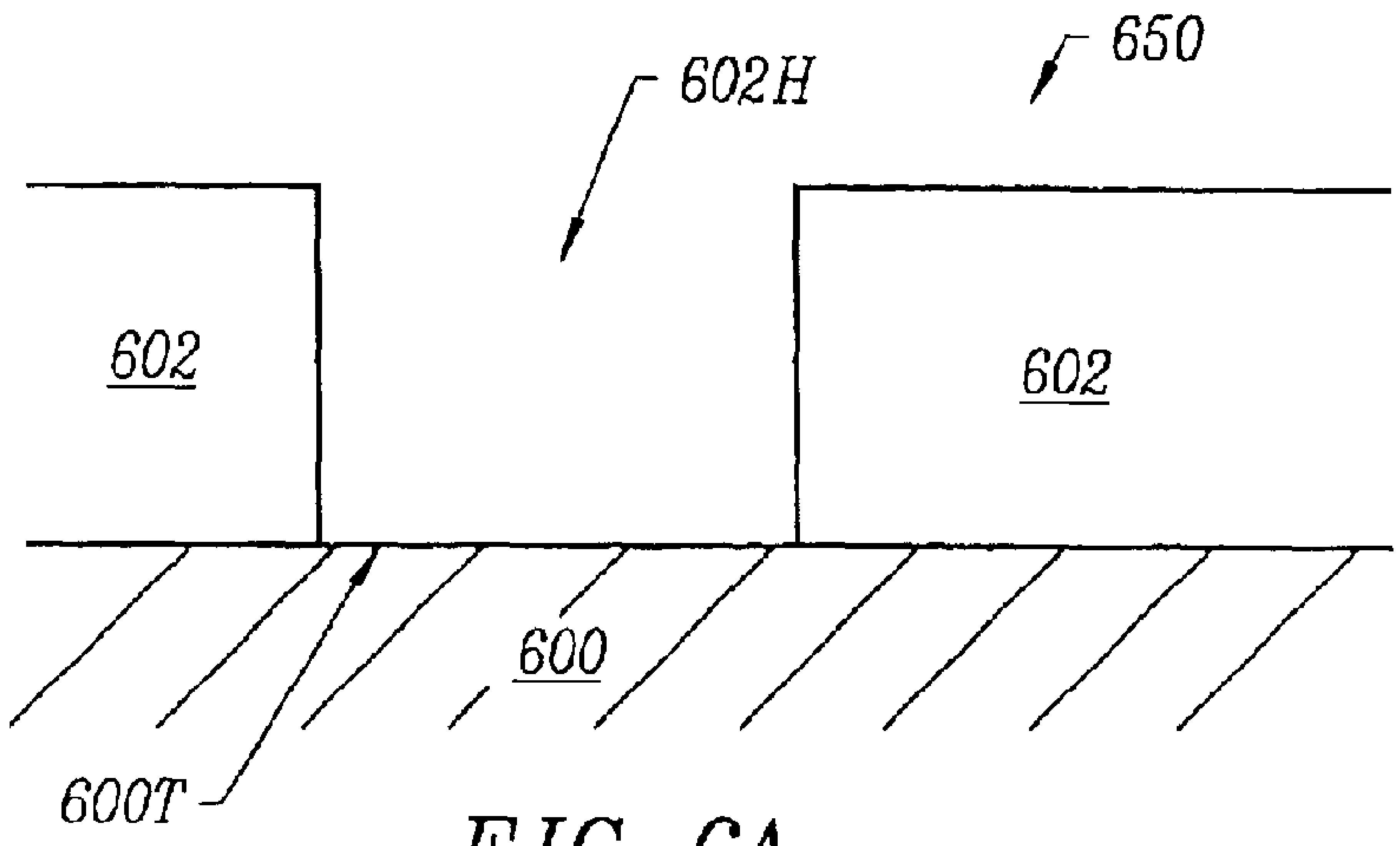

FIG. 6A

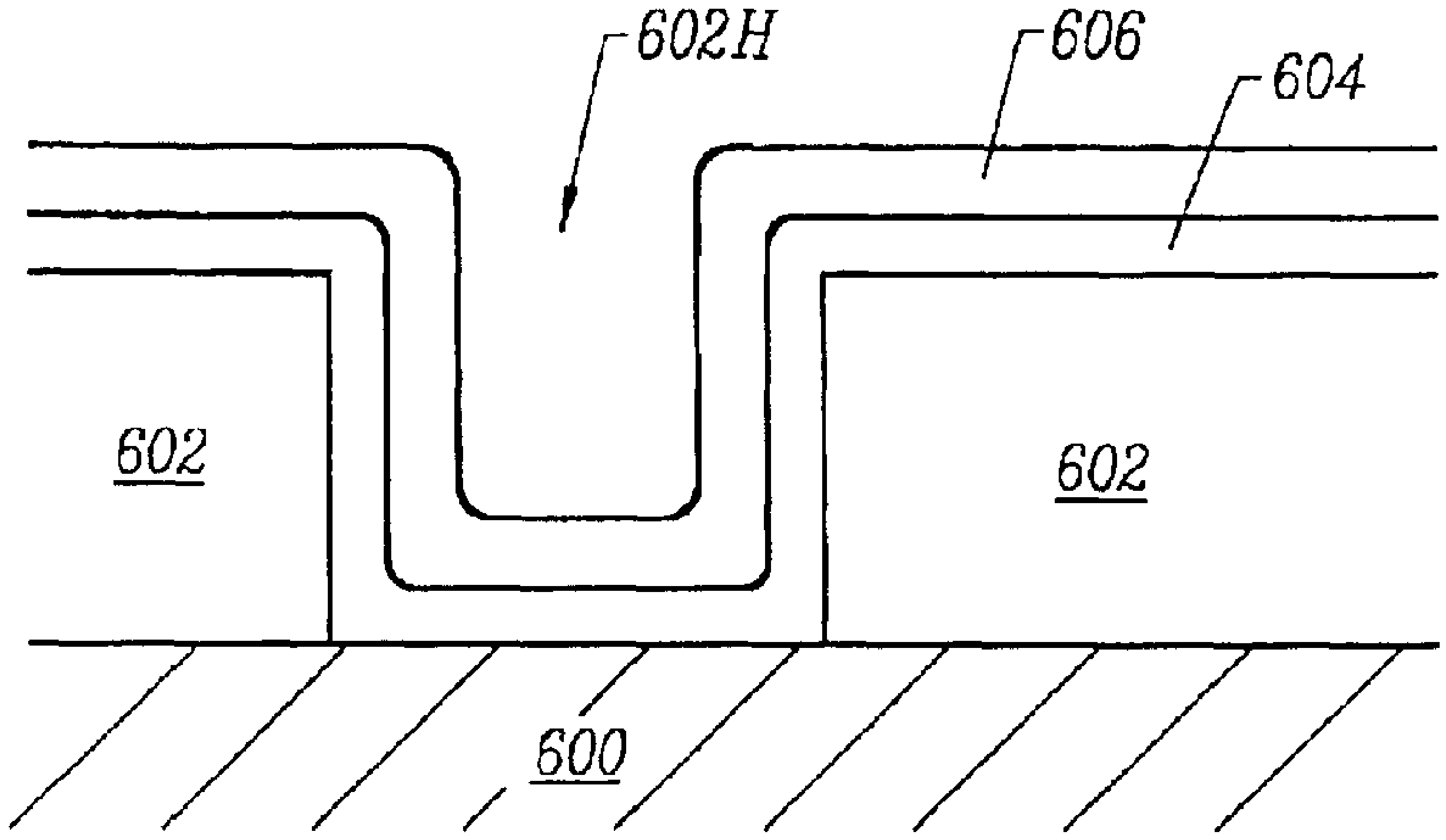

FIG. 6B

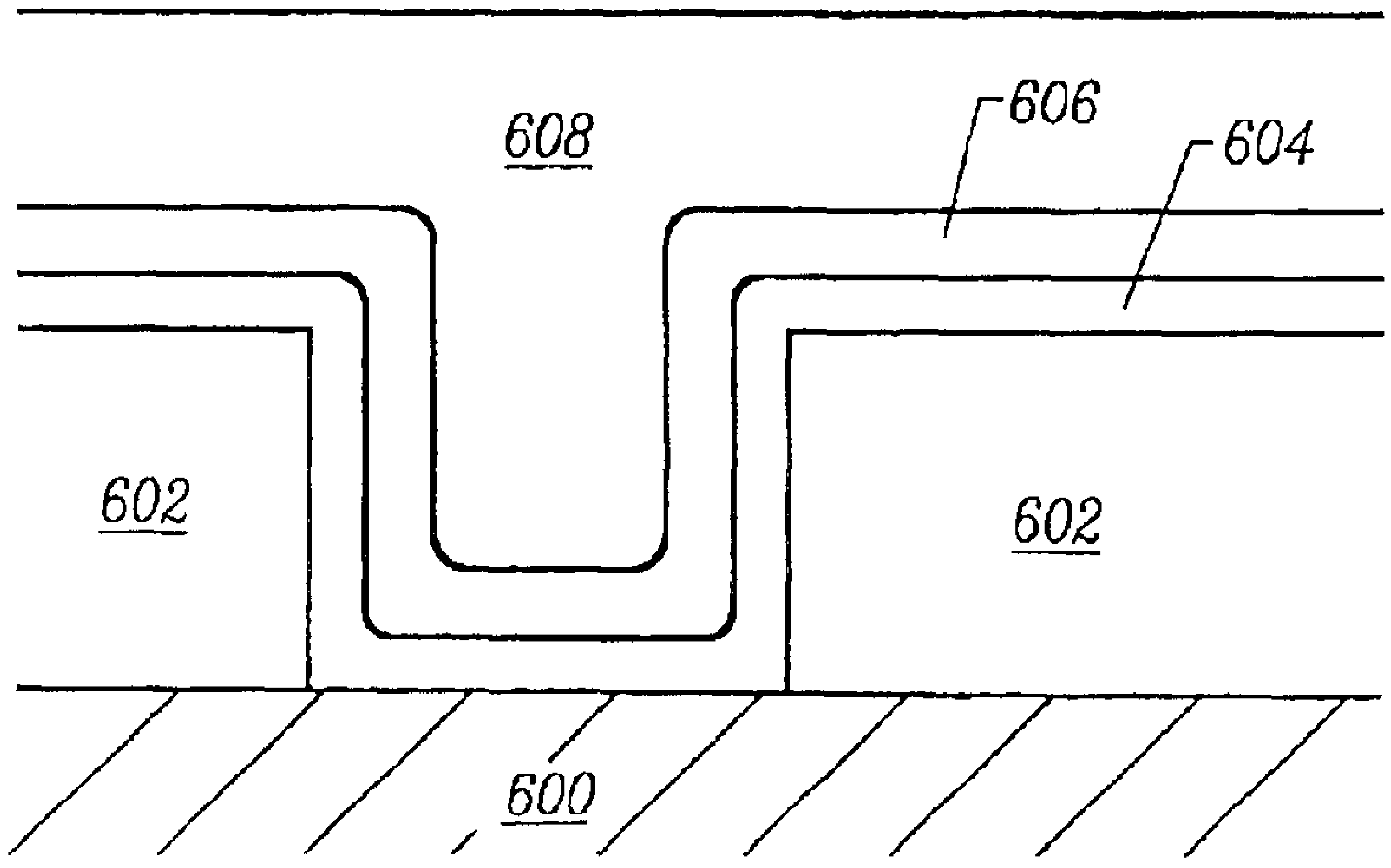

FIG. 6C

FORMATION OF BORIDE BARRIER LAYERS USING CHEMISORPTION TECHNIQUES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 09/604,943, filed Jun. 27, 2000, now U.S. Pat. No. 6,620,723 which is herein incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the formation of boride barrier layers and, more particularly to boride barrier layers formed using chemisorption techniques.

2. Description of the Related Art

In the manufacture of integrated circuits, barrier layers are often used to inhibit the diffusion of metals and other impurities into regions underlying such barrier layers. These underlying regions may include transistor gates, capacitor dielectric, semiconductor substrates, metal lines, as well as many other structures that appear in integrated circuits.

For the current subhalf-micron (0.5 μm) generation of semiconductor devices, any microscopic reaction at an interface between interconnection layers can cause degradation of the resulting integrated circuits (e. g., increase the resistivity of the interconnection layers). Consequently, barrier layers have become a critical component for improving the reliability of interconnect metallization schemes.

Compounds of refractory metals such as, for example, nitrides, borides, and carbides have been suggested as diffusion barriers because of their chemical inertness and low resistivities (e. g., resistivities typically less than about 200 $\mu\Omega$-cm). In particular, borides such as, for example, titanium diboride (TiB_2) have been suggested for use as a barrier material since layers formed thereof generally have low resistivities (e. g., resistivities less than about 150 $\mu\Omega$-cm).

Boride barrier layers are typically formed using chemical vapor deposition (CVD) techniques. For example, titanium tetrachloride ($TiCl_4$) may be reacted with diborane (B_2H_6) to form titanium diboride (TiB_2) using CVD. However, when Cl-based chemistries are used to form boride barrier layers, reliability problems can occur. In particular, boride layers formed using CVD chlorine-based chemistries typically have a high chlorine (Cl) content (e. g., chlorine content greater than about 3%). A high chlorine content is undesirable because the chlorine may migrate from the boride barrier layer into adjacent interconnection layers, which can increase the contact resistance of such interconnection layers and potentially change the characteristics of integrated circuits made therefrom.

Therefore, a need exists in the art for reliable boride barrier layers for integrated circuit fabrication. Particularly desirable would be reliable boride barrier layers useful for interconnect structures.

SUMMARY OF THE INVENTION

Boride barrier layers for integrated circuit fabrication are provided. In one embodiment, the boride barrier layer comprises one refractory metal. The boride barrier layer may be formed by sequentially chemisorbing alternating monolayers of a boron compound and a refractory metal compound onto a substrate.

In an alternate embodiment, a composite boride barrier layer is formed. The composite boride barrier layer comprises two or more refractory metals. The composite boride barrier layer may be formed by sequentially chemisorbing monolayers of a boron compound and two or more refractory metal compounds onto a substrate.

The boride barrier layer is compatible with integrated circuit fabrication processes. In one integrated circuit fabrication process, the boride barrier layer comprises one refractory metal. The boride barrier layer is formed by sequentially chemisorbing alternating monolayers of a boron compound and one refractory metal compound on a substrate. Thereafter, one or more metal layers are deposited on the boride barrier layer to form an interconnect structure.

In another integrated circuit fabrication process, the boride barrier layer has a composite structure. The composite boride barrier layer comprises two or more refractory metals. The composite boride barrier layer is formed by sequentially chemisorbing monolayers of a boron compound and two or more refractory metal compounds on a substrate. Thereafter, one or more metal layers are deposited on the composite boride barrier layer to form an interconnect structure.

BRIEF DESCRIPTION OF THE DRAWINGS

The teachings of the present invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings, in which:

FIG. **1** depicts a schematic illustration of an apparatus that can be used for the practice of embodiments described herein;

FIGS. **2***a*–**2***c* depict cross-sectional views of a substrate structure at different stages of integrated circuit fabrication incorporating a boride barrier layer;

FIGS. **3***a*–**3***c* depict cross-sectional views of a substrate undergoing a first sequential chemisorption process of a boron compound and one refractory metal compound to form a boride barrier layer;

FIGS. **4***a*–**4***d* depict cross-sectional views of a substrate undergoing a second sequential chemisorption process of a boron compound and two refractory metal compounds to form a composite boride barrier layer;

FIGS. **5***a*–**5***d* depict cross-sectional views of a substrate undergoing a third sequential chemisorption of a boron compound and two refractory metal compounds to form a composite boride barrier layer; and

FIGS. **6***a*–**6***c* depict cross-sectional views of a substrate structure at different stages of integrated circuit fabrication incorporating more than one boride barrier layer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** depicts a schematic illustration of a wafer processing system **10** that can be used to form boride barrier layers in accordance with embodiments described herein. The system **10** comprises a process chamber **100**, a gas panel **130**, a control unit **110**, along with other hardware components such as power supplies **106** and vacuum pumps **102**. The salient features of process chamber **100** are briefly described below.

Chamber **100**

The process chamber **100** generally houses a support pedestal **150**, which is used to support a substrate such as a semiconductor wafer **190** within the process chamber **100**. Depending on the specific process, the semiconductor wafer **190** can be heated to some desired temperature prior to layer formation.

In chamber **100**, the wafer support pedestal **150** is heated by an embedded heater **170**. For example, the pedestal **150** may be resistively heated by applying an electric current from an AC power supply **106** to the heater element **170**. The wafer **190** is, in turn, heated by the pedestal **150**, and can be maintained within a desired process temperature range of, for example, about 20° C. to about 500° C.

A temperature sensor **172**, such as a thermocouple, is also embedded in the wafer support pedestal **150** to monitor the temperature of the pedestal **150** in a conventional manner. For example, the measured temperature may be used in a feedback loop to control the electric current applied to the heater element **170** by the power supply **106**, such that the wafer temperature can be maintained or controlled at a desired temperature that is suitable for the particular process application. The pedestal **150** is optionally, heated using radiant heat (not shown).

A vacuum pump **102** is used to evacuate process gases from the process chamber **100** and to help maintain the desired pressure inside the chamber **100**. An orifice **120** is used to introduce process gases into the process chamber **100**. The dimensions of the orifice **120** are variable and typically depend on the size of the process chamber **100**.

The orifice **120** is coupled to a gas panel **130** via a valve **125**. The gas panel **130** provides process gases from two or more gas sources **135**, **136** to the process chamber **100** through orifice **120** and valve **125**. The gas panel **130** also provides a purge gas from a purge gas source **138** to the process chamber **100** through orifice **120** and valve **125**.

A control unit **110**, such as a computer, controls the flow of various process gases through the gas panel **130** as well as valve **125** during the different steps of a wafer process sequence. Illustratively, the control unit **110** comprises a central processing unit (CPU) **112**, support circuitry **114**, and memories containing associated control software **116**. In addition to the control of process gases through the gas panel **130**, the control unit **110** is also responsible for automated control of the numerous steps required for wafer processing—such as wafer transport, temperature control, chamber evacuation, among other steps.

The control unit **110** may be one of any form of general purpose computer processor that can be used in an industrial setting for controlling various chambers and sub-processors. The computer processor may use any suitable memory, such as random access memory, read only memory, floppy disk drive, hard disk, or any other form of digital storage, local or remote. Various support circuits may be coupled to the computer processor for supporting the processor in a conventional manner. Software routines as required may be stored in the memory or executed by a second processor that is remotely located. Bi-directional communications between the control unit **110** and the various components of the wafer processing system **10** are handled through numerous signal cables collectively referred to as signal buses **118**, some of which are illustrated in FIG. **1**.

Boride Barrier Layer Formation

FIGS. **2***a*–**2***c* illustrate one preferred embodiment of boride layer formation for integrated circuit fabrication of an interconnect structure. In general, the substrate **200** refers to any workpiece upon which film processing is performed, and a substrate structure **250** is used to generally denote the substrate **200** as well as other material layers formed on the substrate **200**. Depending on the specific stage of processing, the substrate **200** may be a silicon semiconductor wafer, or other material layer, which has been formed on the wafer. FIG. **2***a*, for example, shows a cross-sectional view of a substrate structure **250**, having a material layer **202** thereon. In this particular illustration, the material layer **202** may be an oxide (e. g., silicon dioxide). The material layer **202** has been conventionally formed and patterned to provide a contact hole **202**H extending to the top surface **200**T of the substrate **200**.

FIG. **2***b* shows a boride layer **204** conformably formed on the substrate structure **250**. The boride layer **204** is formed by chemisorbing monolayers of a boron-containing compound and a refractory metal compound on the substrate structure **250**.

The monolayers are chemisorbed by sequentially providing a boron-containing compound and one or more refractory metal compounds to a process chamber. In a first sequential chemisorption process, the monolayers of the boron-containing compound and one refractory metal compound are alternately chemisorbed on a substrate **300** as shown in FIGS. **3***a*–**3***c*.

FIG. **3***a* depicts a cross-sectional view of a substrate **300**, which may be in a stage of integrated circuit fabrication. A monolayer of a boron-containing compound **305** is chemisorbed on the substrate **300** by introducing a pulse of a boron-containing gas into a process chamber similar to that shown in FIG. **1**. The boron-containing compound typically combines boron atoms **310** with one or more reactive species b **315**. During boride layer formation, the reactive species b **315** form byproducts that are transported from the substrate **300** surface by the vacuum system.

The chemisorbed monolayer of the boron-containing compound **305** is self-limiting in that only one monolayer may be chemisorbed onto the substrate **300** surface during a given pulse. Only one monolayer of the boron-containing compound is chemisorbed on the substrate because the substrate has a limited surface area. This limited surface area provides a finite number of sites for chemisorbing the boron-containing compound. Once the finite number of sites are occupied by the boron-containing compound, further chemisorption of the boron-containing compound will be blocked.

The boron-containing compound may be for example a borane compound having the general formula B_xH_y, where x has a range between 1 and 10, and y has a range between 3 and 30. For example, borane (BH_3), diborane (B_2H_6), triborane, tetraborane, pentaborane, hexaborane, heptaborane, octaborane, nanaborane, and decaborane, may be used as the boron-containing compound.

After the monolayer of the boron compound is chemisorbed onto the substrate **300**, excess boron-containing compound is removed from the process chamber by introducing a pulse of a purge gas thereto. Purge gases such as, for example helium (He), argon (Ar), nitrogen (N_2), ammonia (NH_3), and hydrogen (H_2), among others may be used.

After the process chamber has been purged, a pulse of one refractory metal compound is introduced into the process chamber. Referring to FIG. **3***b*, a layer of the refractory metal compound **307** is chemisorbed on the boron monolayer **305**. The refractory metal compound typically combines refractory metal atoms **320** with one or more reactive species a **325**.

The chemisorbed monolayer of the refractory metal compound **307** reacts with the boron-containing monolayer **305** to form a boride layer **309**. The reactive species a **325** and b **315** form byproducts ab **330** that are transported from the substrate **300** surface by the vacuum system. The reaction of the refractory metal compound **307** with the boron monolayer **305** is self-limited, since only one monolayer of the boron compound was chemisorbed onto the substrate **300** surface.

The refractory metal compound may include refractory metals such as for example titanium (Ti), tungsten (W), tantalum (Ta), zirconium (Zr), hafnium (Hf), molybdenum (Mo), niobium (Nb), vanadium (V), and chromium (Cr), among others combined with reactive species such as, for example chlorine (Cl) and fluorine (F). For example, titanium tetrachloride ($TiCl_4$), tungsten hexafluoride (WF_6), tantalum pentachloride ($TaCl_5$), zirconium tetrachloride ($ZrCl_4$), hafnium tetrachloride ($HfCl_4$), molybdenum pentachloride ($MoCl_5$), niobium pentachloride ($NbCl_5$), vanadium pentachloride (VCl_5), chromium tetrachloride ($CrCl_4$) may be used as the refractory metal compound.

After the monolayer of the refractory metal compound is chemisorbed onto the substrate **300**, any excess refractory metal compound is removed from the process chamber by introducing another pulse of the purge gas therein. Thereafter, as shown in FIG. **3***c*, the boride layer deposition sequence of alternating monolayers of the boron-containing compound and the refractory metal compound are repeated until a desired boride layer thickness is achieved. The boride layer may, for example, have a thickness in a range of about 200 Å to about 5000 Å, and more preferably, about 2500 Å.

In FIGS. **3***a*–**3***c*, boride layer formation is depicted as starting with the chemisorption of a boron-containing monolayer on the substrate followed by a monolayer of a refractory metal compound. Alternatively, the boride layer formation may start with the chemisorption of a monolayer of a refractory metal compound on the substrate followed by a monolayer of the boron-containing compound.

The pulse time for each pulse of the boron-containing compound, the one or more refractory metal compounds, and the purge gas is variable and depends on the volume capacity of the deposition chamber as well as the vacuum system coupled thereto. Similarly, the time between each pulse is also variable and depends on the volume capacity of the process chamber as well as the vacuum system coupled thereto.

In general, the alternating monolayers may be chemisorbed at a substrate temperature less than about 500° C., and a chamber pressure less than about 100 torr. A pulse time of less than about 1 second for the boron-containing compound, and a pulse time of less than about 1 second for the refractory metal compounds are typically sufficient to chemisorb the alternating monolayers that comprise the boride layer on the substrate. A pulse time of less than about 1 second for the purge gas is typically sufficient to remove the reaction byproducts as well as any residual materials remaining in the process chamber.

In a second chemisorption process, the boron-containing monolayers and two or more refractory metal compounds are alternately chemisorbed on the substrate to form a composite boride layer. FIG. **4***a* depicts a cross-sectional view of a substrate **400**, which may be in a stage of integrated circuit fabrication. A self-limiting monolayer of a boron-containing compound **405** is chemisorbed on the substrate **400** by introducing a pulse of a boron-containing compound into a process chamber similar to that shown in FIG. **1** according to the process conditions described above with reference to FIGS. **2***a*–**2***c*. The boron-containing compound combines boron atoms **410** with one or more reactive species b **415**.

After the monolayer of the boron compound **405** is chemisorbed onto the substrate **400**, excess boron-containing compound is removed from the process chamber by introducing a pulse of a purge gas thereto.

Referring to FIG. **4***b*, after the process chamber has been purged, a pulse of a first refractory metal compound M_1a_1 is introduced into the process chamber. A layer of the first refractory metal compound **407** is chemisorbed on the boron monolayer **405**. The first refractory metal compound typically combines first refractory metal atoms M_1 **420** with one or more reactive species a_1 **425**.

The chemisorbed monolayer of the first refractory metal compound **407** reacts with the boron-containing monolayer **405** to form a boride monolayer **409**. The reactive species a_1 **425** and b **415** form byproducts a_1b **430** that are transported from the substrate **400** surface by the vacuum system.

After the monolayer of the first refractory metal compound **407** is chemisorbed onto the substrate **400**, the excess first refractory metal compound M_1a_1 is removed from the process chamber by introducing another pulse of the purge gas therein.

Another pulse of the boron-containing compound is than introduced into the process chamber. A monolayer of the boron-containing compound **405** is chemisorbed on the first refractory metal monolayer **407**, as shown in FIG. **4***c*. The chemisorbed monolayer of the boron-containing compound **405** reacts with the first refractory metal monolayer **407** to form a boride layer **409**. The reactive species a_1 **425** and b **415** form byproducts a_1b **430** that are transported from the substrate **400** surface by the vacuum system.

After the monolayer of the boron compound **405** is chemisorbed onto the first refractive metal monolayer **407**, excess boron-containing compound is removed from the process chamber by introducing a pulse of a purge gas thereto.

Referring to FIG. **4***d*, after the process chamber has been purged, a pulse of a second refractory metal compound M_2a_1 is introduced into the process chamber. A layer of the second refractory metal compound **411** is chemisorbed on the boron monolayer **405**. The second refractory metal compound typically combines second refractory metal atoms M_2 **440** with one or more reactive species a_1 **425**.

The chemisorbed monolayer of the second refractory metal compound **411** reacts with the boron-containing monolayer **405** to form the composite boride layer **409**. The reactive species a_1 **425** and b **415** form byproducts a_1b **430** that are transported from the substrate **400** surface by the vacuum system.

After the monolayer of the second refractory metal compound **411** is chemisorbed onto the substrate **400**, the excess second refractory metal compound M_2a_1 is removed from the process chamber by introducing another pulse of the purge gas therein.

Thereafter, the boride layer deposition sequence of alternating monolayers of the boron-containing compound and the two refractory metal compounds M_1a_1 and M_2a_1 are repeated until a desired boride layer thickness is achieved.

In FIGS. **4***a*–**4***d*, boride layer formation is depicted as starting with the chemisorption of the boron-containing monolayer on the substrate followed by monolayers of the two refractory metal compounds. Alternatively, the boride layer formation may start with the chemisorption of monolayers of either of the two refractory metal compounds on the substrate followed by monolayers of the boron-containing compound. Optionally, monolayers of more than two refractory metal compounds may be chemisorbed on the substrate **400**.

In a third chemisorption process, the boron-containing monolayers and two or more refractory metal compounds are alternately chemisorbed on the substrate to form a composite boride layer, as illustrated in FIGS. **5***a*–**5***d*.

FIG. **5***a* depicts a cross-sectional view of a substrate **500**, which may be in a stage of integrated circuit fabrication. A self-limiting monolayer of a first refractory metal compound **507** is chemisorbed on the substrate **500** by introducing a pulse of a first refractory metal compound M_1a_1 into a process chamber similar to that shown in FIG. **1** according to the process conditions described above with reference to FIGS. **2***a*–**2***c*.

After the monolayer of the first refractory metal compound **507** is chemisorbed onto the substrate **500**, excess first refractory metal compound is removed from the process chamber by introducing a pulse of a purge gas thereto.

Referring to FIG. **5***b*, after the process chamber has been purged, a pulse of a second refractory metal compound M_2a_1 is introduced into the process chamber. A layer of the second refractory metal compound **511** is chemisorbed on the first refractory metal monolayer **507**.

After the monolayer of the second refractory metal compound **511** is chemisorbed onto the substrate **500**, the excess second refractory metal compound M_2a_1 is removed from the process chamber by introducing another pulse of the purge gas therein.

A pulse of a boron-containing compound is than introduced into the process chamber. A monolayer of the boron-containing compound **505** is chemisorbed on the second refractory metal monolayer **511**, as shown in FIG. **5***c*. The chemisorbed monolayer of the boron-containing compound **505** reacts with the second refractory metal monolayer **511** to form a composite boride layer **509**. The reactive species a_1 **525** and b **515** form byproducts a_1b **530** that are transported from the substrate **500** surface by the vacuum system.

After the monolayer of the boron compound **505** is chemisorbed onto the second refractory metal monolayer **511**, excess boron-containing compound is removed from the process chamber by introducing a pulse of a purge gas thereto.

Referring to FIG. **5***d*, after the process chamber has been purged, a pulse of the first refractory metal compound M_1a_1 is introduced into the process chamber. A monolayer of the first refractory metal compound **507** is chemisorbed on the boron monolayer **505**.

The chemisorbed monolayer of the first refractory metal compound **507** reacts with the boron-containing monolayer **505** to form the boride monolayer **509**. The reactive species a_1 **525** and b **515** form byproducts a_1b **530** that are transported from the substrate **500** surface by the vacuum system.

After the monolayer of the first refractory metal compound **507** is chemisorbed onto the substrate **500**, the excess first refractory metal compound M_1a_1 is removed from the process chamber by introducing another pulse of the purge gas therein.

Thereafter, the boride layer deposition sequence of alternating monolayers of the boron-containing compound and the two refractory metal compounds M_1a_1 and M_2a_1 are repeated until a desired boride layer thickness is achieved.

In FIGS. **5***a*–**5***d*, boride layer formation is depicted as starting with the chemisorption of the first refractory metal monolayer on the substrate followed by monolayers of the second refractory metal compound and the boron-containing compound. Alternatively, the boride layer formation may start with the chemisorption of the monolayer of the boron-containing compound on the substrate followed by the monolayers of the two refractory metal compounds. Optionally, monolayers of more than two refractory metal compounds may be chemisorbed on the substrate **500**.

The sequential deposition processes described above advantageously provide good step coverage for the boride layer, due to the monolayer chemisorption mechanism used for forming the boride layer. In particular, boride layer formation using the monolayer chemisorption mechanism is believed to contribute to a near perfect step coverage over complex substrate topographies.

Furthermore, in chemisorption processes, since only one monolayer may be absorbed on the topographic surface, the size of the deposition area is largely independent of the amount of precursor gas remaining in the reaction chamber once a monolayer has been formed.

Referring to FIG. **2***c*, after the formation of the boride layer **204**, a contact layer **206** may be formed thereon to complete the interconnect structure. The contact layer **206** is preferably selected from the group of aluminum (Al), copper (Cu), tungsten (W), and combinations thereof.

The contact layer **206** may be formed, for example, using chemical vapor deposition (CVD), physical vapor deposition (PVD), or a combination of both CVD and PVD. For example, an aluminum (Al) layer may be deposited from a reaction of a gas mixture containing dimethyl aluminum hydride (DMAH) and hydrogen (H_2) or argon (Ar) or other DMAH containing compounds, a CVD copper layer may be deposited from a gas mixture containing $Cu^{+2}(hfac)_2$ (copper hexafluoro acetylacetonate), $Cu^{+2}(fod)_2$ (copper heptafluoro dimethyl octanediene), Cu^{+1}hfac TMVS (copper hexafluoro acetylacetonate trimethylvinylsilane), or combinations thereof, and a CVD tungsten layer may be deposited from a gas mixture containing tungsten hexafluoride (WF_6). A PVD layer is deposited from a copper target, an aluminum target, or a tungsten target.

FIGS. **6***a*–**6***c* illustrate an alternate embodiment of boride layer formation for integrated circuit fabrication of the interconnect structure. In general, the substrate **600** refers to any workpiece upon which film processing is performed, and a substrate structure **650** is used to generally denote the substrate **600** as well as other material layers formed on the substrate **600**. Depending on the specific stage of processing, the substrate **600** may be a silicon semiconductor wafer, or other material layer, which has been formed on the wafer. FIG. **6***a*, for example, shows a cross-sectional view of a substrate structure **650**, having a material layer **602** thereon. In this particular illustration, the material layer **602** may be an oxide (e. g., silicon dioxide). The material layer **602** has been conventionally formed and patterned to provide a contact hole **602**H extending to the top surface **600**T of the substrate **600**.

FIG. **6***b* shows two boride layers **604**, **606** conformably formed on the substrate structure **650**. The boride layers **604**, **606** are formed by chemisorbing monolayers of a boron-containing compound and one or more refractory metal compounds on the substrate structure **650** as described above with reference to FIGS. **3***a*–**5***d*. The two boride layers **604**, **606** may each comprise one or more refractory metals. The thicknesses of the two or more boride layers **604**, **606** may be variable depending on the specific stage of processing. Each boride layer **604**, **606** may, for example, have a thickness in a range of about 200 Å to about 5000 Å.

Referring to FIG. **6***c*, after the formation of the boride layers **604**, **606**, a contact layer **608** may be formed thereon to complete the interconnect structure. The contact layer **608** is preferably selected from the group of aluminum (Al), copper (Cu), tungsten (W), and combinations thereof.

The specific process conditions disclosed in the above discussion are meant for illustrative purposes only. Other combinations of process parameters such as precursor and inert gases, flow ranges, pressure and temperature may also be used in forming the boride layer of the present invention.

Although several preferred embodiments, which incorporate the teachings of the present invention, have been shown and described in detail, those skilled in the art can readily devise many other varied embodiments that still incorporate these teachings.

What is claimed is:

1. A method of forming a film on a substrate, comprising:

positioning the substrate having an oxide layer thereon; and

forming at least one metal boride layer on at least a portion of the substrate by sequentially chemisorbing monolayers of a boron-containing compound and one or more refractory metal compounds on the substrate to form the at least one metal boride layer thereon, wherein the at least one metal boride layer is formed using a sequential chemisorption process.

2. The method of claim **1**, wherein the substrate is subjected to a purge gas following chemisorption of each monolayer.

3. The method of claim **1**, wherein the boron-containing compound has general formula B_xH_y, where x has a range between 1 and 10, and y has a range between 3 and 30.

4. The method of claim **3**, wherein the boron-containing compound is selected from the group consisting of borane, diborane, triborane, tetraborane, pentaborane, hexaborane, heptaborane, octaborane, nonaborane and decaborane.

5. The method of claim **1**, wherein the one or more refractory metal compounds are selected from the group consisting of titanium tetrachloride, tungsten hexafluoride, tantalum pentachloride, zirconium tatrachloride, hafnium tetrachloride, molybdenum pentachloride, niobium pentachloride, vanadium chloride, and chromium chloride.

6. The method of claim **1**, wherein forming at least one metal boride layer is performed at a temperature less than about 500° C.

7. The method of claim **1**, wherein forming at least one metal boride layer is performed at a pressure less than about 100 Torr.

8. The method of claim **2**, wherein the purge gas is selected from the group of helium, argon, hydrogen, nitrogen, ammonia, and combinations thereof.

9. The method of claim **1**, wherein monolayers of the boron-containing compound and the one or more refractory metal compounds are alternately chemisorbed on the substrate.

10. The method of claim **9**, wherein one monolayer of the boron-containing compound is chemisorbed between each chemisorbed monolayer of the one or more refractory metal compounds.

11. The method of claim **9**, wherein one monolayer of the boron-containing compound is chemisorbed on the substrate after two or more monolayers of the one or more refractory metal compounds are chemisorbed thereon.

12. The method of claim **1**, wherein the at least one metal boride layer has a thickness less than about 100 Å.

13. The method of claim **1**, wherein the at least one metal boride layer has a thickness in a range of from about 200 Å to about 5,000 Å.

14. A method of forming a layer on a substrate for use in integrated circuit fabrication, comprising:

positioning the substrate within a deposition chamber; and

forming a boride layer comprising tungsten on at least a portion of the substrate by sequentially chemisorbing monolayers of a boron-containing compound and a tungsten-containing compound on the substrate.

15. A method of film deposition for integrated circuit fabrication, comprising:

placing a substrate within a deposition chamber;

introducing a boron-containing compound into the chamber;

chemisorbing at least a portion of the boron-containing compound on the substrate at conditions sufficient to form a boron-containing layer;

evacuating the chamber;

introducing at least one refractory metal compound into the chamber;

reacting a portion of the at least one refractory metal compound with the boron-containing layer at conditions sufficient to form a metal boride containing layer; and

evacuating the chamber.

16. The method of claim **15**, wherein the metal boride containing layer comprises at least one refractory metal selected from the group consisting of titanium, tungsten, vanadium, niobium, tantalum, zirconium, hafnium, chromium and molybdenum.

17. The method of claim **15**, wherein the at least one refractory metal compound is selected from the group consisting of titanium tetrachloride tungsten hexafluoride, tantalum pentachloride, zirconium tetrachloride, hafnium tetrachloride molybdenum pentachloride, niobium pentachloride, vanadium chloride and chromium chloride.

18. The method of claim **15**, wherein the boron-containing compound has the general formula B_xH_y, where x has a range from 1 to 10 and y has a range from 3 to 30.

19. The method of claim **15**, wherein the boron-containing compound is selected from the group consisting of borane, diborane, triborane, tetraborane, pentaborane, hexaborane, heptaborane, octaborane, nonaborane and decaborane.

20. The method of claim **15**, wherein the conditions sufficient to form the metal boride containing layer comprises a temperature of about 500° C. or less.

21. The method of claim **15**, wherein the conditions sufficient to form the metal boride containing layer comprises a pressure of about 100 Torr or less.

22. The method of claim **15**, further comprising purging the deposition chamber with at least one purge gas selected from the group consisting of helium, argon, hydrogen, nitrogon, ammonia and combinations thereof.

23. The method of claim **15**, wherein the metal boride containing layer comprises at least two refractory metals.

24. The method of claim **15**, wherein the metal boride containing layer has a thickness from about 200 Å to about 5,000 Å.

25. A method of film deposition for integrated circuit fabrication, comprising:

placing a substrate within a deposition chamber;

introducing at least one refractory metal compound into the chamber;

chemisorbing a portion of the at least one refractory metal compound on the substrate to form refractory metal containing layer;

evacuating the chamber;

introducing a boron-containing compound into the chamber;

reacting at least a portion of the boron-containing compound with the refractory metal containing layer at conditions sufficient to form a metal boride containing layer; and

evacuating the chamber.

26. The method of claim **25**, wherein the metal boride containing layer comprises at least one refractory metal selected from the group consisting of titanium, tungsten, vanadium, niobium, tantalum, zirconium, hafnium, chromium and molybdenum.

27. The method of claim **25**, wherein the at least one refractory metal compound is selected from the group consisting of titanium tetrachloride, tungsten hexafluoride, tantalum pentachloride, zirconium tetrachloride, hafnium tetrachloride, molybdenum pentachloride, niobium pentachloride, vanadium chloride and chromium chloride.

28. The method of claim **25**, wherein the boron-containing compound has the general formula B_xH_y, where x has a range from 1 to 10, and y has a range from 3 to 30.

29. The method of claim **25**, wherein the boron-containing compound is selected from the group consisting of borane, diborane, triborane, tetraborane, pentaborane, hexaborane, heptaborane, octaborane, nonaborane and decaborane.

30. The method of claim **25**, wherein the conditions sufficient to from the metal boride containing layer comprises a temperature of about 500° C. or less.

31. The method of claim **25**, wherein the conditions sufficient to form the metal boride containing layer comprises a pressure of about 100 Torr or less.

32. The method of claim **25**, further comprising purging the deposition chamber with at least one purge gas selected from the group consisting of helium, argon, hydrogen, nitrogen, ammonia and combinations thereof.

33. The method of claim **25**, wherein the metal boride containing layer comprises at least two refractory metals.

34. The method of claim **25**, wherein the metal boride containing layer has a thickness from about 200 Å to about 5,000 Å.

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